

Lenné3D – Walking through Landscape Plans

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*Only by its relationship to human
does landscape attain its completion.*

Peter Joseph Lenné (1789-1866)

1 Introduction

Human landscape perception is based on a complex aesthetic functional context. Only through the intellectual processing of what has been seen, does the detailed visual information of a landscape turn into what we call “landscape”. In this interaction, the aesthetic product “landscape” mainly results from the driving forces “education”, “experience” and “enjoying observation” (contemplation). This interrelation is very familiar to the profession of landscape planning and design. It is therefore surprising that planning contents are rarely presented in a coherent and stimulating manner. Reading and interpreting maps takes a significant cognitive effort (ZUBE ET AL., 1987). While professional planners are able to rely on their experience to help them to visualize proposed landscapes, laypersons are usually overwhelmed by abstract, graphically sparse mapping and other forms of representation. They are unable to translate this information into landscape images and landscape reality.

Landscape planning would therefore benefit greatly from technological developments of 3D visualization tools. Such tools should be used to support the information exchange between planners and laypersons in a new and more intuitive way. They should translate Repton’s idea with his *Red Books* to draw different planning situations from the viewer’s perspective (DANIELS, 1999) into a new dimension. The notion already was to give the decision maker better information by experiencing familiar impressions and performing common activities.

In addition, new visualization tools would be helpful to support interdisciplinary scientific communication in landscape research (BRYAN, 2003). Results from various real world landscape analysis, simulations or assessments could be jointly presented and much more easily discussed among different disciplines and professional backgrounds.

2 The Feasibility Study

In the year 2000, the Leibniz Centre for Agricultural Landscape Research (ZALF) conducted a “Feasibility Study for a Visualization Tool” (HERWIG ET AL., 2000). The aims of this research project were to gain an overview of available software for 3D landscape

visualizations, and to assess and determine the requirements and potential demand for new 3D landscape visualization technology for landscape research as well as landscape and environmental planning. Within the context of the feasibility study, a survey of current and potential professional users of 3D visualization software in Germany was conducted (JÜNEMANN ET AL., 2001, BUHMANN & JÜNEMANN, 2000). The survey was designed to identify deficits of available landscape simulation software and to provide direction for both software developers and users. In addition, a case study was undertaken, in which a participatory landscape project was supported with interactive 3D computer simulations created by adapting computer-game technology (HERWIG & PAAR, 2002).

2.1 Software Development Goals

The results of the case study and the user requirements identified had been discussed by specialists from the fields of computer graphics and landscape simulations in a workshop (PAAR, 2003). The results highlighted the need for an innovative new 3D visualization tool with the following features (HERWIG ET AL., 2000):

1. *Geodata-based*: the visualization system uses prevalent landscape and planning data in standard (GIS) data formats. Plans and scenarios have to be expressed as GIS themes. The visualization system reads the GIS data and generates 3D landscape scenes.
2. *Real-time and 3D*: landscape is primarily visualized in three spatial dimensions enabling real-time navigation, and the opportunity to “look around” and “move about” (DANAHY, 2001). Navigation (motion in the landscape) is a constitutional factor of spatial cognition and understanding.
3. *First person view*: landscape is primarily visualized from an eye-level perspective enabling to wander through the planned or predicted landscape.
4. *Sketch and photorealistic rendering*: landscape has to be represented in different modes in order to clarify the conceptual and process-related character of planning and design: a) photorealistic visualizations in the form of static and moving images; b) interactive visualizations with reduced graphic detail; c) interactive visualizations with sketchy rendition (DEUSSEN, 2001).
5. *Convincing representation of plants and biotopes*: as most landscapes are covered with vegetation, the representation of plants and vegetation is a prerequisite for realistic visual simulations of landscape sceneries.
6. *Active-parallel interactivity*: the system enables decisions to be tested virtually by exploring visualizations of the resultant scenery. In the planning process new ideas are produced, e.g. by stakeholders; these notes and suggestions can be stored in the 3D scene for further evaluation, and visualization where appropriate.
7. *Visualization of the invisible*: a single simulation of the visual landscape scenery has the potential drawback of a partial aesthetics-driven communication. Ecological and economical background information is needed for a holistic understanding of landscape complexity, especially when assessing the effects of alternative landscape settings. Thus, non-visual processes and states of the natural environment are intuitively represented and illustrated.
8. *PC-based*: the system runs on standard PCs with off-the-shelf gaming graphic boards.
9. *Usability*: Navigation and control of the real-time renderer is user-friendly; authoring and compilation of 3D landscape scenes is easily learnable from typical GIS users.

2.2 Further Demands

In the meantime, authors like APPLETON ET AL. (2002) draw similar conclusions. TRESS & TRESS (2003) point out: “It would be ideal to have a powerful and photo-realistic GIS-based visualization tool with dynamic characteristics that would show landscape from the perspective of a moving observer” (p. 173). APPLETON ET AL. (2002) conclude that there is no “universal landscape visualization solution”, and that current technology forces users to make trade-offs in detail and interactivity. They see a market gap for a visualization tool that can be used in combination with GIS, and predict that future visualization technology will move towards the combined goals of availability, geographic detail, realism and interactivity. ORLAND (1992) demands that visualization techniques for environmental management must include analyses and modeling tools, and should support multiple scales, i.e. detailed change at the local level within the framework of coarse-grained data sets. ERVIN (2001) recommends that research and development of landscape modeling should be carried out in close cooperation with computer scientists. REKITTKE (2002, p. 121) argues that the profession of landscape planning “(...) must be prepared to keep up to date with current developments in the field of digital technology and, if necessary, develop solutions tailored to its needs”.

We have also been inspired by the developments of ‘polyTRIM’ (toolkit for representation interaction and modeling), which was developed in the 1990ies at the Center of Landscape Research (CLR), and which runs on Silicon Graphics high-end workstations (DANAHY & HOINKES, 1995). CLR was able to break new ground in the field of real-time simulations for academic research and education in urban and landscape planning (STEINITZ, 1992; HOINKES & LANGE, 1995).

3 Material & Methods of the Lenné3D Project

Since May 2002, *Lenné3D* (www.lenne3d.de) – the subsequent R+D-project of the feasibility study – is addressing this challenge, making use of cutting-edge technology from developments in computer graphics as well as computer games techniques to enhance civic participation in landscape planning and design. Among those contributing to this collaborative, interdisciplinary research project are several computer graphics scientists, landscape planners and landscape architects, as well as a biologist and a crop scientist. The German Federal Environmental Foundation (DBU) supported the *Lenné3D* research project. *Lenné3D* is a cooperative project of the ZALF, Inst. of Land Use Systems and Landscape Ecology, the Zuse-Institut Berlin (ZIB), Dept. of Visualization and Data Analysis, the University of Konstanz, Dept. of Computer and Information Science, Chair Media Informatics, and the Hasso-Plattner-Institute for Software Systems Engineering (HPI), Chair Computergraphical Systems, Potsdam.

3.1 Input Data

In order to have access to the growing availability of geo-databases, it is necessary that the visualization tool uses typical geo-data and standard formats. The Lenné3D software needs:

- Digital Elevation Model (DEM, e.g. formats: BT, ESRI GRID);
- Biotope type map(s) (format: ESRI Shapefile);
- Regional vegetation data (reference relevés, format: XML) (RÖHRICHT, 2005);
- Lenné3D plant models (format: TXF, i.e. Xfrog-based);
- 3D objects (format: 3ds);
- Orthophotos (format: e.g. Tiff);
- Additional geodata (format: e.g. topographical, pedological, historical data).

3.2 Software System

The software architecture of the Lenné3D system designates two main components: the *LandXplorer* (DÖLLNER ET AL., 2003) for the assembly, exploration and editing of landscape data, and the *3D-Player* for the interactive landscape visualization from first person view. This partitioning arises from the implementation of specialized and optimized computer-graphics systems, developed as separate projects, for each of the two components. Both of these main components employ the *oik* component, developed for the generation of spatial plant distribution (Fig. 1).

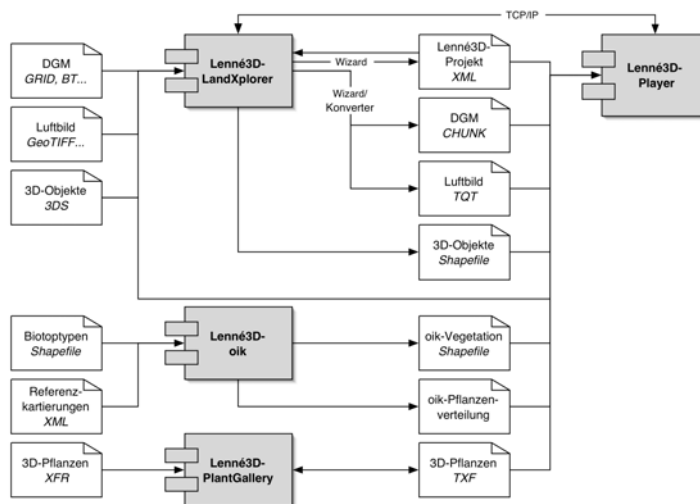


Fig. 1: Software architecture of the Lenné3D prototype

The *LandXplorer* is based on the authoring software for 3D maps and 3D city models *LandEx* (www.landex.de), which is being developed further for application in the field of landscape planning. Analysis and editing functions, which serve to ascertain planning parameters, have been integrated into the *LandXplorer* especially to fulfill the requirements of vegetation modeling. With the *LandXplorer*, *Lenné3D* projects are created and managed. This component can also integrate and transform geo-data.

The *3D-Player* is a program that interprets the scenic description and geo-data specified in a *Lenné3D* project. 3D vegetation models are assigned to the plant distribution calculated by the *oik* component and positioned within the landscape model. At the forefront of this technology is the development of the Level of Detail (LoD) process for the dynamic reduction of the overall complexity of sceneries. The geometric and color complexity of the landscape model must be drastically reduced in order to perform real-time simulations in the *3D-Player*, but this reduction must remain imperceptible to the viewer. This requires that the relevant visual information is conveyed and packaged in suitable data structures for efficient data processing and quick access (COCONU & HEGE, 2002; DEUSSEN ET AL., 2005). The latest computer graphics techniques allow a large number of images to be generated and calculated per second. Triangles of the complex model are progressively replaced with fewer primitives (e.g. points and lines) as the camera moves away.

The *oik* component calculates plant positions by means of heuristic-algorithmic models, on the basis of habitat data (biotope types), reference mappings and topographical site data. In cooperation with the company *greenworks organic software*, best known for its *Xfrog* software (DEUSSEN, 2003), a wide range of central European plant life, particularly foliage, has been modeled. Plants commonplace in central Europe are selected, and supplemented by species typical of the region in which the testing areas are situated. The 3D plants are modeled for the *3D-Player* in full spring appearance. This decision was made for reasons of working capacity, as well as the fact May-June seems the most suitable phenological reference season for visual simulation, as the vegetation is most lush at this time. Woody plants are also modeled for a winter view.

4 Testing in Practice

Using real examples of landscape planning, the research and development team is engaged in testing application of the prototype system and developing the process of stakeholder participation and decision-making supported by computer graphics. In order to guarantee development of a system that will stand up to professional use, landscape planners are directly involved in the application design of the software. Furthermore, bi-annual seminars with professional experts and potential professional users are conducted to hear their assessments and criticisms of latest developments in the research project.

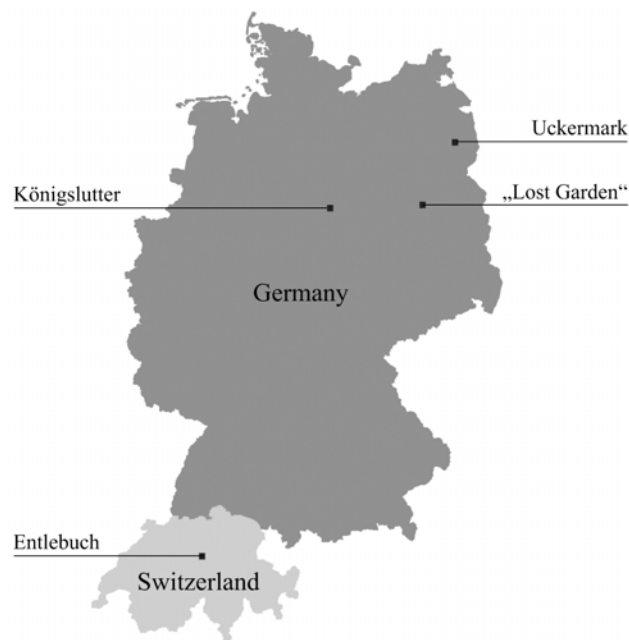


Fig. 2: Map with Lenné3D case studies in Germany and Switzerland

4.1 Agricultural Site Uckermark

The first testing started in a 1.4 ha site in the main research area of the ZALF (Uckermark district). With respect to soils, topography, hydrology and land use systems, this region is typical for North-Eastern Germany as well as Eastern Europe. This geodata set has been serving as a testbed for modeling and rendering approaches (COCONU ET AL., 2005).



Fig. 3: Screenshots from the interactive Lenné3D-Player; left and centre: visualizations of the state before and after removing the farm building (2003); right: foreground detail with higher plant density, and more plant species (2004)

4.2 Interactive Landscape Plan Königsutter

In early 2003, the first case study started within the framework of the project “Interactive Landscape Plan” in the township of Königsutter, granted by the German Federal Office for Nature Conservation (BfN, Bonn). The aim of the collaboration is to test the Lenné3D system in practice under the conditions of a participative landscape planning process, and to evaluate its acceptance by stakeholders and planners and results in an accompanying survey. In collaboration with this project, a slope was selected for high-detailed landscape visualization, in discussion with local stakeholders. The area, which is predominantly used for agriculture, is situated at the edge of the Elm Natural Park, Germany and is affected by water erosion of the topsoil. The town wishes to enhance soil protection, promote landscape related recreation and protect the local natural species and habitats. Further results are presented in WARREN-KRETZSCHMAR & TIEDKE (2005).

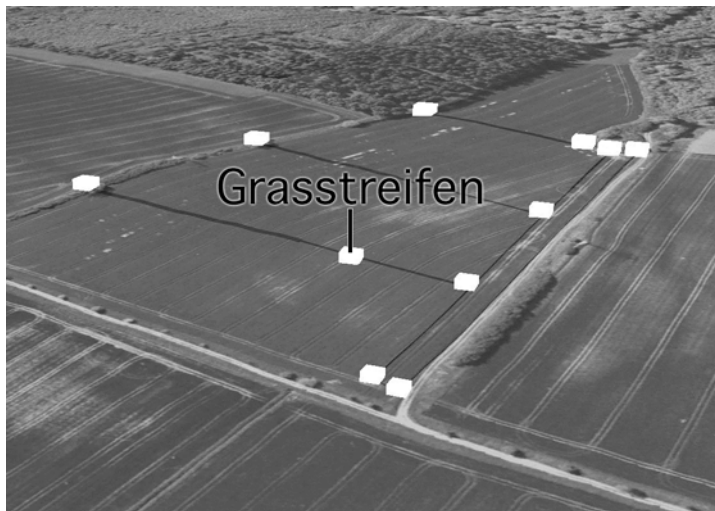


Fig. 3: Using the Lenné3D-LandXplorer stakeholders' comments could be interactively located in the landscape model during the discussion with text, icons, lines, and polygons.

4.3 The Lost Garden in Park Sanssouci

A “lost garden”, the former “Italian cultural showpiece” was a jewel of the Potsdam-Berlin park and garden landscape, largely arranged by Peter Joseph Lenné, and a designated part of the UNESCO world cultural heritage. The garden was laid out in 1834 to the west of the Roman Baths in Sanssouci park in order to complete the atmosphere of an Italian country villa as created by the Roman baths. Grape vines and pumpkins once grew as garlands scalloping between elm and mulberry trees, between ornamental and useful plants from the Mediterranean, thus emphasizing the agricultural character of the Roman Baths. Many of the plants used are not winter-hardy in central Europe, their cultivation is demanding and

their care is very labor intensive. Within only 50 years after its creation nothing remained of the garden.

Today it would be simple to recreate the system of paths, however the time consuming maintenance of the garden is hardly to be implemented due to the tremendous amount of labor. In this case, a computer simulation is the ideal means to provide experts and the general public with an impression of the former diversity of the horticultural garden. The 3D model of the lost garden was composed jointly by scientists of the garden management of the Foundation for Prussian Palaces and Gardens in Berlin and Brandenburg (SPSG) and the Lenné3D team. As no historical pictures existed, the exact list of plants and the layout of the entire area had to be compiled on the basis of the few general plans, written descriptions and the analogies to historically existing useful plants.

In summer 2004, more than 20,000 people visited the exhibition “Prussian Green. From Royal Court Gardeners to Curators of a Historical Garden Heritage” where the virtually reconstructed Garden of the 19th century was presented to the public. For a heightened visual garden experience, the Lenné3D-Player generated images were projected onto a concave 180° panorama screen (Fig. 4). By means of a tangible interface especially developed for the application, the visitor, standing in the half circle of the screen, is able to choose his own path through the garden in an intuitive manner and thus immerse himself in the virtual world. The lightwheel (Fig. 4, right) represents the viewer’s location and highlights his viewshed on the map. In fact, while most of the visitors became quickly acquainted with the setting, others were confused, expecting that the image detail would move to the opposite direction while rotating the lightwheel to the other. These people probably did not understand the map metaphor of the desk.



Fig. 4: Interactive visualization of the lost garden; 180° panoramic projection with lightwheel device (designed by Brygg Ullmer, ZIB) to navigate the virtual walk (Photo left: SPSG; photo right: Ullmer)

4.4 Alpine Landscape in Switzerland

The prototype of the Lenné3D system is undergoing further testing as part of the European research project ‘VisuLands – Visualization Tools for Public Participation in the Management of Landscape Change’ (LANGE ET AL., 2003). Here, a Swiss team is evaluating different visualization methods for use with various scales, degrees of detail and interactivity (PAAR ET AL., 2004). First results are expected in spring 2005.

5 Highlights of the Lenné3D System

According to the addressed goals (section 2) the Lenné3D system provides powerful tools with unique features to semi-automatically prepare and depict the visual construct of landscapes.

1. *Real-time and details:* Lenné3D offers interactive visualization supporting high levels of detail.
2. *Plants:* Botanically accurate and detailed Lenné3D plant models; largest repertory for central European landscapes, jointly developed with greenworks organic software using Xfrog software;
3. *Vegetation:* Modeling of vegetation and plant distribution. Plant growth and landscape change can be represented in timeslices that have to be modeled (RÖHRICHT, 2005);
4. *Representation choices:* Photo-realistically, sketched or graphically reduced and cartographic representation;
5. *View choices:* 3D map view and stroller’s perspective. In the 3D map view the viewer is hovering above the landscape in any height and with any angle of view. The stroller’s perspective is termed First Person View in the world of computer games and represents the common personal experience of the layperson;
6. *Non-visuals:* Visualization of unobservable or invisible meta-information (first examples in REKITKE & PAAR, 2005);
7. *Scale independence:* Multiscalability to visualize the landscape from large-scale terrains to a single habitat with detailed plants based on one geo-database;
8. *Geodata-based:* The LandXplorer and the oik component read, interpret and write geodata. Both components support a semi-automated transformation of 2D plans into 3D landscape scenes;
9. *Collaborative visualization and landscape editing:* Especially the LandXplorer supports the planning and design process with interactive editing functions in three dimensions. For collaborative visualization 3D-Player and LandXplorer running on different systems can be remote-controlled using TCP-IP. This is used for view synchronization or interactive planting of trees in 3D map view and real-time visualization in the 3D-Player.

6 Conclusions & Outlook

Current technological developments within computer graphics will assist 3D landscape visualization tools in fulfilling the specific requirements of landscape planners and environmental managers. The above mentioned feasibility study and survey highlighted the need for innovative new 3D landscape visualization tools.

The possibility of having high-class visualizations is no guarantee for an implementation of the planned landscape. But accurate and carefully chosen visualizations support the dialogue on community landscape planning and decision making.

Lenné3D enables members of the general public, as well as professionals, to examine and explore landscape data, and additionally supports the planning and design process with interactive editing functions in three dimensions, thereby generating interest and ideas among the general public (WARREN-KRETZSCHMAR & TIEDKE, 2005). The software enables decisions to be tested virtually by exploring visualizations of the resultant scenery and meta-information. However, the question of how effective is such an approach compared to traditional ways of communicating between planner and stakeholder, and to what degree tools like *Lenné3D* will be helpful in the planning processes, requires more investigation. Technology has reached a point where scientists are enabled to “[...] selectively manipulate certain characteristics of a scene, while holding all other features constant” (KILLEEN & BUHYOFF, 1983), e.g. in experimental studies on landscape preference or representational validity of landscape visualizations.

Further approaches to develop the *Lenné3D* system include activities for enhancing performance, creating more real-time enabled 3D plant models, implement more “physics” (e.g. illumination, CLASEN & HEGE, 2005), and adding new features to support the intuitive use of the tool. In a next step, research and development will be necessary to implement the dimension of time into the visualization process. The change of visual aspects of landscape over time, e.g. seasonal aspects and vegetation development, remains an interdisciplinary task for further research and development projects.

7 Acknowledgements

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9 References

- Appleton, K., A. Lovett, G. Sünnerberg & T. Dockerty (2002): *Rural landscape visualisation from GIS databases: a comparison of approaches, options and problems*. Computers, Environment and Urban Systems, 26: 141-162.

- Bryan, B.A. (2003): *Physical environmental modeling, visualization and query for supporting landscape planning decisions*. Landscape and Urban Planning, 65: 237-259.
- Buhmann, E. & P. Jünemann (2000): Umfrage zur Machbarkeitsstudie für ein Visualisierungstool. Internal report on behalf of the ZALF. URL: <http://www.zalf.de>
- Clasen, M. & H.-Ch. Hege (2005): *Realistic Illumination of Vegetation in Real-Time Environments*, this volume.
- Coconu, L., C. Colditz, H.-Ch. Hege & O. Deussen (2005): *Seamless Integration of Stylized Renditions in Computer-Generated Landscape Visualization*, this volume.
- Coconu, L. & H.-Ch. Hege (2002): *Hardware-Accelerated Point-Based Rendering of Complex Scenes*. Proc. of the 13th Eurographics Workshop on Rendering Techniques, Pisa, Italy: 43–52.
- Danahy, J.W. (2001): *Technology for dynamic viewing and peripheral vision in landscape visualization*. Landscape and Urban Planning, 54: 125-137.
- Danahy, J.W., & R. Hoinkes (1995): *Politrin: collaborative setting for environmental design*. In: M. Tan, & R. The (eds.), The Global Design Studio. Proc. of the CAAD Futures '95, CASA, 24-26 September 1995, National University of Singapore: 647-658.
- Daniels, S. (1999): *Humphry Repton: Landscape Gardening and the Geography of Georgian England*, Paul Mellon Center BA, New Haven.
- Deussen, O. (2003): *A framework for geometry generation and rendering of plants with applications in landscape architecture*. Landscape and Urban Planning, 64 (1-2): 105-113.
- Deussen, O. (2001): *Nichtrealistische Computergraphik: Algorithmen und Anwendungen*. Informatik-Spektrum 24 (3), März 2001, Springer.
- Deussen, O., C. Colditz, L. Coconu & H.-Ch. Hege (2005): *Efficient modelling and rendering of landscapes*. In: Bishop, I. & E. Lange (eds.), Visualization in landscape and environmental planning, Spon Press, London: 56-61.
- Döllner, J., K. Baumann & O. Kersting (2003): *LandExplorer - ein System für interaktive 3D-Karten*. Kartographische Schriften, Band 7, Kirchbaumverlag, Hannover, März 2003: 67-76.
- Ervin, S.M. (2001): *Digital landscape modeling and visualization: a research agenda*. Landscape and Urban Planning 54 (1-4): 49-62.
- Herwig, A. & P. Paar (2002): *Game Engines: Tools for Landscape Visualization and Planning?* In: E. Buhmann, U. Nothelfer & M. Pietsch (eds.): Trends in GIS and Virtualization in Environmental Planning and Design. Proc. at Anhalt University of Applied Sciences, Wichmann, Heidelberg: 162-171.
- Herwig, A., P. Paar, J. Rekittke & A. Werner (2001): *Machbarkeitsstudie für ein Visualisierungstool. Analyse des Bedarfes und der Machbarkeit eines computergraphischen Visualisierungssystems für interaktive Planungs- und Umsetzungsprozesse auf Landschaftsebene – Ergebnisbericht [Final Report]*. ZALF, Müncheberg (unpublished).
- Herwig, A., P. Paar, J. Rekittke & A. Werner (2000): *Interaktive 3D-Landschaftsvisualisierung aus der Spaziergängerperspektive – Vorstellung einer Machbarkeitsstudie für ein Visualisierungs-Tool*. In: Schmidt, B. & C. Uhlenkücken (Hrsg.), Visualisierung raumbezogener Daten: Methoden und Anwendungen, Bd. II (IfGIprints, Schriftenreihe des Instituts für Geoinformatik, Westfälische Wilhelms-Universität Münster, 8): 133-144.

- Hoinkes, R. & E. Lange (1995): *3D for free: toolkit expands visual dimensions of GIS*. GIS World Mag., 8 (7), 54–56.
- Jünemann, P., P. Paar. & J. Rekittke (2001): *Landschaftsplanung: Verbreitung und Einsatz von 3D-Visualisierungswerkzeugen in der Planungspraxis*. Kartografische Nachrichten (KN), 4, Themenschwerpunkt Geovisualisierung: 200-204.
- Killeen, K. & G. Buyhoff (1983): *The Relation of Landscape Preference to Abstract Topography*. Journal of Environmental Management, 17: 381-392).
- Orland, B. (1992): *Data visualization techniques in environmental management: a consolidated research agenda*. Landscape and Urban Planning, 21: 241-244.
- Paar, P. (2003): *Lenné3D – The Making of a New Landscape Visualization System: From Requirements Analysis and Feasibility Survey towards Prototyping*. In: E. Buhmann & S. Ervin (eds.): Trends in Landscape Modeling. Proc. at Anhalt University of Applied Sciences, Wichmann, Heidelberg: 78-84.
- Paar, P. & J. Rekittke (2005): *Lenné3D – Walk-through Visualization of Planned Landscapes*. In: Bishop, I. & E. Lange (eds.), Visualization in landscape and environmental planning, Spon Press, London: 152-162.
- Paar, P., O. Schroth, U. Wissen, E. Lange, E. & W.A. Schmied (2004): *Steckt der Teufel im Detail? Eignung unterschiedlicher Detailgrade von 3D-Landschaftsvisualisierung für Bürgerbeteiligung und Entscheidungsunterstützung*. CORP 2004, TU Vienna: 535-541.
- Rekittke, J. & P. Paar (2005): *Enlightenment Approaches for Digital Absolutism. Diplomatic stepping-stones between the real and the envisioned*, this volume.
- Rekittke, J. (2002): *Drag and Drop - The Compatibility of Existing Landscape Theories and New Virtual Landscapes*. In: Buhmann, E., U. Nothelfer & M. Pietsch (Eds.), Trends in GIS and Virtualization in Environmental Planning and Design, Proc. at Anhalt University of Applied Sciences. Heidelberg: Wichmann: 110-123.
- Röhrich, W. (2005): *oik - nulla vita sine dispensatio. Vegetation Modelling for Landscape Planning*, this volume.
- Steinitz, C. (1992): *Alternative Futures for the Snyderville Basin*, Summit County. Utah. School of Design, Harvard University, MA.
- Tress, B., & G. Tress (2003): *Scenario visualization for participatory landscape planning – a study from Denmark*. Landscape and Urban Planning, 64: 161-178.
- Warren-Kretschmar, B. & S. Tiedke (2005): *What Role Does Visualization Play in Communication with Citizens? – A Field Study from the Interactive Landscape Plan*, this volume.
- Zube, E.H., D.E. Simcox, & C.S. Law (1987): *Perceptual landscape simulations: history and prospect*. Landscape Journal, 6 (1): 62-80.